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SCIENTIFIC EVIDENCE AND THE ABANDONMENT OF MEDICAL TECHNOLOGY: A STUDY OF EIGHT DRUGS

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I. INTRODUCTION

Researchers and decision-makers have shown considerable interest in the determinants of adoption of technological innovation by professionals. At the same time, comparatively little attention has been paid to the abandonment of technology.

Classic research on adoption of innovation includes extensive theoretical work describing the process and empirical evidence drawn from a wide range of settings to support it.[1,2,3] Abandonment of technology, on the other hand, has seldom been the object of much more than casual mention. Several studies have examined the declining use of specific technologies,[4,5,6,7] but most have not systematically considered the process or its implications.

In the study to be described, we examine the declining use, over time of eight technologies, all pharmaceuticals, by a professional group, practitioners of medicine. For the sake of argument, we begin by assuming that the abandonment of these drugs might appropriately be viewed as a reverse of the process of adoption - the "acceptance" of a piece of "negative" information, first by "opinion leaders" and then others whom they influence. We will, however, offer empirical evidence that causes us to seriously doubt the validity of that assumption. We discuss the possible significance of our observations and suggest some directions for further study.

II. ADOPTION THEORIES AND EMPIRICAL STUDIES

Adoption of technological innovation has been one of the more intensively studied intellectual issues of the twentieth century. Social scientists and management scientists made it the object of literally thousands of articles containing a mix of theories and empirical data.[8] One body of literature focuses on the identification of important attributes of the technologies or adopters and their influence on the acceptance of the innovations. Another kind of study proposes and tests an analytic formulation as a model of the adoption process.

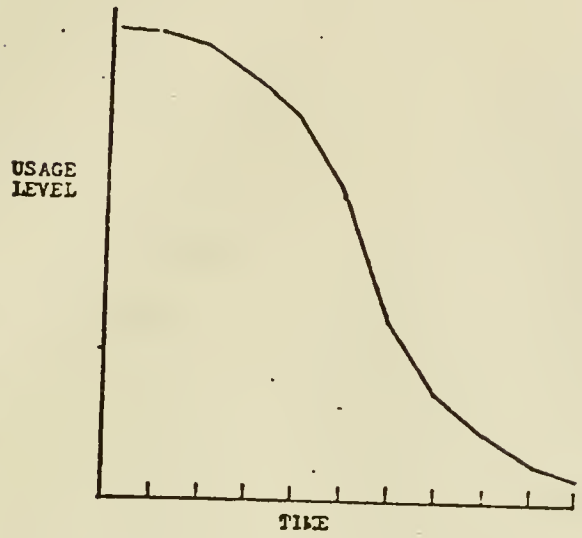
A common thread that runs through much of the adoption research is a concept of contagion or spread, borrowed from the biology of epidemics, and an S-shaped curve that describes it (see Figure 1). The lower part of the curve slopes slightly upward to reflect the initial adoption of the technology by the relatively few opinion leaders who learn of it from some external stimulus and who later influence others. The middle part of the curve slopes steeply to reflect the increasing number of users as the reputation of the practice spreads. After the innovation has been in use for some time and its potential is nearly reached, growth in the number of adopters slows and the slope of the adoption curve becomes flat at the limit.

The mathematical form of the S-shaped curve was described early as a logistic function[9] (See Equation 1) of form:

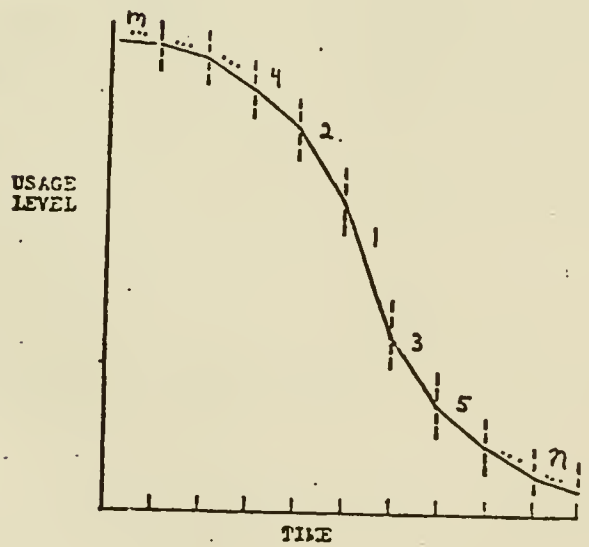
$$(1) \quad dN/dt = kN\,(\bar{N} - N)$$

FIGURE 1

a. The S-Shaped Curve



b. Rankings of Periods Used in Test of S-Shaped Curve



relating the change over time (t) in the number of adopters (N) of the technology to a coefficient of spread (k) times the product of adopters and non-adopters ($\overline{N}$-N). ($\overline{N}$ is the universe of all potential users.) The logistic model was shown empirically to offer a close fit to S-shaped patterns of innovation adoption in a number of industries ranging from industrial products to medicine.

Despite the success in empirically relating S-shaped logistic curves to the process of adoption of technology, some have found it to be less than completely satisfactory. Among the drawbacks of the logistic model are its failures to account for "external" influences or control variables such as advertising or price reductions undertaken explicitly to influence adoption. Some researchers have offered modifications to these logistic models which have been associated with even closer empirical fits than the traditional S-shaped curve.[10,11,12] A prominent example is the work of Bass in the late 1960s, described in Equation 2, which assumes that non adopters ($\overline{N}$-N) could be persuaded to become adopters as a result of either internal or external stimuli.[10] If the "coefficient of innovation" (a) is set to 0, the logistic model remains, with the "coefficient of imitation" (b) equivalent to the constant (k) in equation 1.

$$2) \quad dN/dt = (a + bN)(\overline{N} - N)$$

The Bass model and the other variants of the traditional logistic function offered to explain innovation-adoption about which we are aware still have S-shaped graphical representations. In our review of the literature, we were unable to identify any research that systematically

considered whether the abandonment of technology could appropriately be described by an analytic model of one of these forms or another form.

III. THE MEDICAL CONTEXT

What causes physicians to adopt medical technologies has been the object of research by medical and social scientists.[6,7,13,14,15,16,17] Most studies have focused on identifying sources of information from which potential adopters of an innovation learned of its existence. The content of that information has been less intensively studied, but it has largely been taken for granted that one of the principal factors that drives adoption is the relative advantage of the innovation over current practice.

One important study of adoption focused on pharmaceutical innovation and was carried out by Coleman, Katz, and Menzel in the 1950s.[13] This major empirical study examined the adoption process associated with a new antibiotic drug, "gammanym", the third in a series of related pharmaceuticals, following "alphanym" and "betanym." Their study utilized prescription records of physicians practicing in four midwestern communities, and also included structured interviews with the physicians about the determinants of their drug adoption behavior, the nature of their practices, and the structure of the colleague networks with whom or through whom they communicated. The findings from their study suggested a two-step process by which physicians learn about and go on to adopt new drugs. The first step involves opinion leaders, highly respected physicians practicing in the community, who find out about the new drug innovations from external sources, predominantly drug manufacturers'

promotional activity. The bulk of the practitioners, however, adopted gammanym as a result of a chain reaction; that is, they learned about it from the colleagues with whom they regularly communicated informally.

As in other fields, determinants of the abandonment of medical technology have received less attention than those affecting adoption. Published reports have addressed the abandonment of particular pharmaceuticals such as explosive anesthetic agents[7] and drugs to lower blood sugar or blood cholesterol.[18] In contrast to the usual reasons to adopt a new practice, the rationale for abandonment can include absolute as well as relative disadvantages. For example, a drug can suffer declining use because it appears to be harmful or ineffective, even if a more desirable substitute practice is not clearly identifiable.

IV. APPROACH

Our approach was to study the pattern of decline of drugs introduced to market following the 1962 amendments to the federal Food and Drug Act. This legislation enhanced the importance of medical evidence of safety and effectiveness in determining what pharmaceuticals were available to physicians in prescribing for their patients. We obtained the list of all chemically new drugs, numbering 45, that were introduced during the period 1963-1972, allowing us to track the utilization of each of these agents for at least eight to ten years. We intentionally narrowed the sample by excluding those drugs (26) which failed a test of visibility or importance to practitioners based upon the number of times they were mentioned in key periodicals or because their "target audience" was largely limited to diseases of low incidence.

For 18 of the remaining 19 drugs, we were able to gain access to market research data that describes changes in usage over time following its introduction to market through 1980 or 1981. The time-series data on drug usage was drawn from the "estimated appearances" measure in annual reports from the National Disease and Therapeutic Index (NDTI) of IMS America, Ltd. This NDTI measure is a projection of the number of times the drug was recommended as a treatment by a physician in the U.S. during a patient visit. For seven of the drugs remaining in the sample, the data reflected an unmistakable pattern of decline, eventually reaching a fall from its peak of 40% or more. These seven drugs did not include any for which the Food and Drug Administration used its authority to remove a drug from the market; under such circumstances, the observed pattern of decline in use would not be very meaningful.

An additional drug was added to the sample, bringing the total number of innovations to be examined to 8. Tolbutamide, a prominent oral treatment for diabetes until it was largely discredited by a highly-controversial clinical study,was actually introduced before 1962. However, we included it in our study because of its importance in medical practice and because much of its adoption and later abandonment took place during the time period we were examining. We also accessed NDTI time series data on the use of this pharmaceutical.

Our principal aim in this analysis is to consider whether or not the pattern of abandonment observed in the time series data suggests support for a chain-reaction type of diffusion process and its associated S-shaped curve. But recognizing the limitations of that kind of data in explaining behavior, we sought to establish the plausibility of a cause and effect relationship between the medical evidence of either absolute

disadvantage (i.e., harmful and/or ineffective) or relative disadvantage (compared to substitute) and the observed decline of each of these drugs. To accomplish this, we analyzed the timing and content of related articles, editorials, and letters in representative journal literature and news media whose messages could have contributed to the abandonment of these drugs. We developed a chronology of important events for each drug in our study after selecting our "representative" journals on the basis of the classification system of Narin and colleagues.[19] The Journal of the American Medical Association and the New England Journal of Medicine, two of the most influential English language periodicals, were used most frequently. We also used the New York Times index to track public visibility of these technologies.

Our quantitative analysis is based upon Spearman's rank order correlation test which compares two lists, each rank-ordered according to a different criterion. The Spearman coefficient, r_s ranges from -1 to 1, with 1 indicating total agreement in the rankings.

An S-shaped curve representing abandonment of an innovation would be characterized by its period of greatest decline in the middle, with progressively smaller decreases on either side. The greater the distance from the middle of the curve, the smaller the magnitude of the decline.* The first of the two criteria for ranking the periods is the "theoretical expected" decline, as shown in Figure 1. The middle period was assigned the rank of 1. This is the period where the greatest decline would be expected. The ranking continued alternating from one side of the middle to the other. The rank gives an indication of the distance from the

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*For simplicity, a symmetric S-shaped curve was assumed for this analysis.

middle of the curve. The second criterion for ranking was the magnitude of the absolute decline experienced during each period. Acceptance of the null hypothesis of no correlation suggests the absence of strong support for the S-shaped model. Positive correlation, rejecting the null hypothesis, would support the existence of the S-shaped curve and the traditional adoption/diffusion model with which it is consistent.

V. ANALYSIS AND RESULTS

To examine the change over time in the patterns of medical evidence bearing on the eight drugs in our sample, we catalogued the publication history of professional opinion about the use of each of these agents. Each of the "abandoned" drugs in our study was linked to unfavorable medical evidence relating to either safety or efficacy, or both. The usage pattern of only one of the pharmaceuticals we studied was clearly affected by an identifiable competing product that might have served to encourage its abandonment, but this drug also was tied to negative findings in its own right. Table 1 summarizes the actions and problems associated with the "discredited" drugs we studied. The identified date of first recognition or publication of the negative information must be considered approximate because of the subjective nature of the cataloguing process and because we only looked at selected key periodicals.

The usage over time of each of the drugs we studied declined to at least 40 percent of its peak usage by 1980. Our convention was to consider the decline to have started during the year following the one in which its usage peaked. Figures 2-9 describe the decline in use observed

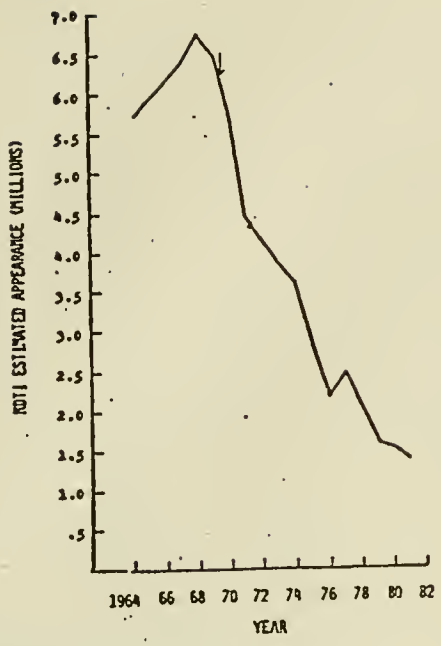
Table 1

Actions and Problems
With Eight "Abandoned" Drugs Under Study

Drug	Action	Key Unfavorable Medical Reports	Approx. Date First Published/Recognized
Tolbutamide	Lowers blood sugar	Safety/Efficacy	1970
Clofibrate	Lowers blood cholesterol	Safety/Efficacy	1975
Clindamycin	Antibiotic	Safety	1974
*Ethacrynic Acid	Diuretic	Safety	1969
Fentanyl and Droperidol	Adjunct to anesthetic	Safety	1973
Indomethacin	Anti-inflammatory	Safety/Efficacy	1967
Pentazocine	Analgesic	Safety/Efficacy	1969
Propoxyphene	Analgesic	Safety/Efficacy	1968

*A competing product was clearly involved.

FIGURE 2

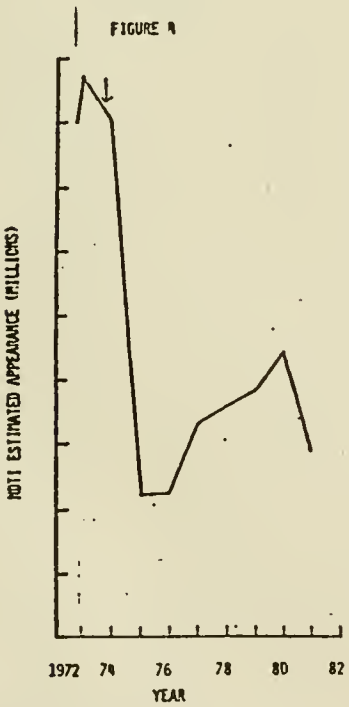


USE OF TOLBUTAMIDE, 1966-1981
SOURCE: NATIONAL DISEASE AND THERAPEUTIC INDEX

FIGURE 3

USE OF CLOFIBRATE, 1973-1981
SOURCE: RATIONAL DISEASE AND THERAPEUTIC INDEX

FIGURE 4

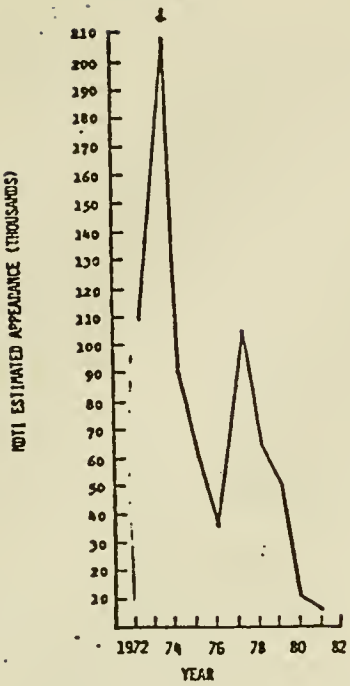


USE OF CLINDAMYCIN, 1973-1981
SOURCE: NATIONAL DISEASE AND THERAPEUTIC INDEX

FIGURE 5

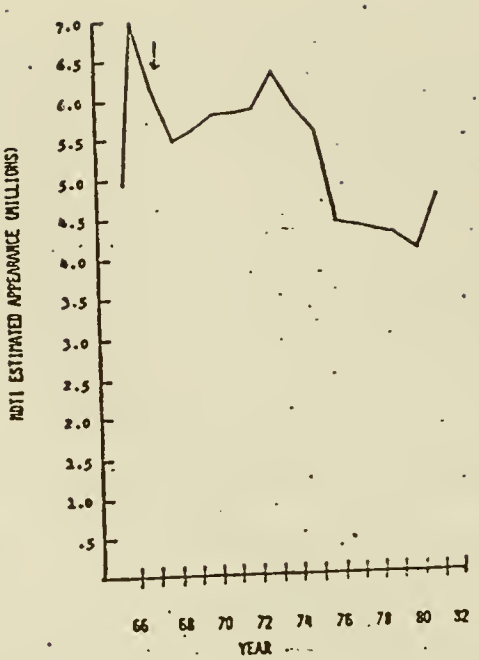
USE OF ETHACRYNIC ACID, 1967-1981
SOURCE: NATIONAL DISEASE AND THERAPEUTIC INDEX

FIGURE 6



USE OF FENTANYL AND DROPERIDOL, 1972-1981
SOURCE: NATIONAL DISEASE AND THERAPEUTIC INDEX

FIGURE 7

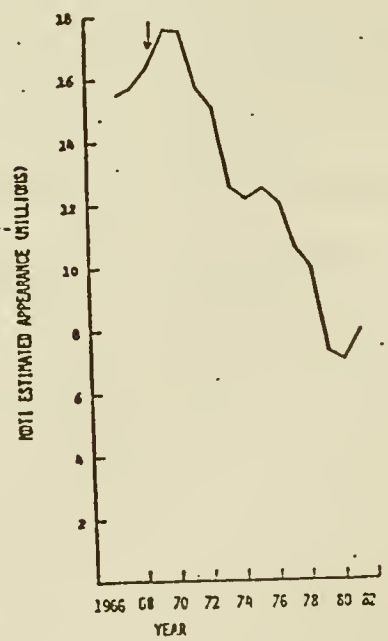


USE OF INDOMETHACIN, 1966-1981
SOURCE: NATIONAL DISEASE AND THERAPEUTIC INDEX

FIGURE 8

USE OF PENTAZOCINE, 1968-1981
SOURCE: NATIONAL DISEASE AND THERAPEUTIC INDEX

FIGURE 9



USE OF PROPOXYPHENE, 1966-1981
SOURCE: NATIONAL DISEASE AND THERAPEUTIC INDEX

for each. The approximate date of first publication of negative medical evidence questioning safety and/or efficacy of the product is indicated by an arrow. Note that the beginning of the decline of each agent was roughly chronologically consistent with the recognition of the unfavorable medical information; in a few cases the negative information seemed to precede the beginning of the decline by a short time. Not all of our cases showed a monotonic decline following publication of this information. Some were associated with periods of increased use or level use, but the trend toward abandonment was unmistakable over the time period extending from the earliest data reported, through 1981.

Next, we tested whether the process of abandonment of the drugs under study was consistent with an S-shaped curve, a form usually considered to be consistent with a traditional innovation-adoption model in which information is first adopted by opinion leaders who go on to influence others. We used the Spearman rank order correlation test to examine whether or not our empirical data offered support for an S-shaped curve in the manner described earlier. Table 2 shows the rankings and the results can be found in Table 3. The values of the Spearman coefficient of correlation r_s from the test of the S-shaped curve are scattered around zero. Five are negative and three are positive. Rejecting the null hypothesis of no correlation would offer support for the S-shaped model. In this case the null hypothesis is not rejected, indicating a poor fit with the S-shaped curve. In particular, it is a poor fit of the basic characteristic of the S-shaped curve, that the largest decline occurs in the middle. Instead, the results tend to show usage patterns that follow paths in which the absolute decline is largest at the beginning.

Table 2

Comparison of Rank of Magnitude of Actual Usage Decline with that Predicted by an S-shaped Model

(A) Interval From S-Shaped Curve in Decreasing Order of Expected Magnitude of Decline (See Figure 1)	Rank of Magnitude of Decline Occurring that Interval								(B) Average Across
	Tolbutamide	Clofibrate	Clinda-mycin	Ethacrynic Acid	Fentany and Droperidol	Indo-methacin	Penta-zocine	Propoxy-phene	
1	2	6	5	10	2	5	8	7	5.63
2	10	4	8	4	8	14	10	11	8.63
3	4	2	6	9	6	4	7	4	5.25
4	7	1	4	8	5	11	12	8	6.75
5	13	5	7	7	3	1	6	6	6
6	8	3	1	3	4	10	1	2	4
7	6		2	13	7	7	9	1	6.43
8	1		3	5	1	13	2	5	4.29
9	5			9		9	3	9	7
10	3			1		12	4	3	4.6
11	12			11		8	11	12	10.6
12	9			2		3	5	10	5.8
13	11			12		6			9.66

Table 3

Results from Test of S-shaped Model of Drug Abandonment Using the Spearman Rank Order Correlation Test

Drug	r_s
Tolbutamide	.25
Clofibrate	-.09
Clindamycin	-.57
Ethacrynic Acid	-.06
Fentanyl and Droperidol	-.24
Indomethacin	.01
Pentazocine	-.26
Propoxyphene	.13

Because the inability to offer support for an S-shaped abandonment function in the test described above was based upon only 6-13 ranked pairs for each of the eight drugs in the sample, we decided to look elsewhere for evidence. On the same assumption that an S-shaped function, if the appropriate model for describing the abandonment of drugs, should demonstrate declines of greatest magnitude in the center of the curve, we made a supplementary calculation. For each drug, we examined the ranking of the actual magnitude of decline observed during the period that our model predicted should be the time period showing the greatest decline (Period 1 on Figure 1). We continued the process beginning with the time period expected, under the assumptions of the model, to have the next largest decline (Period 2 on Figure 1) through the period predicted to show the smallest decline (Period m or n on Figure 1). Results can be found in Table 2, columns A and B. Support for the validity of the S-shaped model would be manifest if the average ranking for the eight drugs in a specific time interval (Column B) were to approach the ranking predicted by the model (Column A). But, as can be seen, in the period when the greatest decline was expected, the observed decline was typically around the median in the successive drops in drug usage. The average ranking of magnitude of decline shown in the "center" time period should approach the value of one, if the s-model is to be supported. As can be seen in Table 2, no such support for the S-shaped curve is forthcoming from this supplementary calculation.

VI. DISCUSSION

Our results strongly suggest that for the eight "abandoned" drugs we studied, medical evidence of "absolute disadvantage" played an important

role in their declining use and that the process of abandonment does not appear to be consistent with a contagion model and its S-shaped curve.

In contrast to much of the previous writing about adoption of technological innovation, the technologies we studied did not appear to be judged on the basis of a comparative advantage or disadvantage over a substitute practice. Fully seven of the forty-five chemically new drugs introduced during the ten year period 1963-72, and tolbutamide, introduced earlier, all showed unmistakable signs of "abandonment" by 1981. The observed declines in usage appear to be largely driven by evidence of harmful side effects and/or lack of efficacy of each.

When there is no new product to displace - or being displaced - there is reason to expect less emphasis on advertising to influence physician drug prescribing behavior unless the manufacturer were to explicitly undertake a campaign directed at countering the effects of the negative medical evidence. In fact, in the 8 instances we studied, expenditures on direct mail, detailing, and journal advertising fell roughly in proportion to the observed declines in the use of each drug, suggesting that the manufacturers spent proportionately to revenues, instead of counter-attacking.[20]

The diminished importance of "incremental advantage" in the abandonment of these drugs is not the only reason to suspect that the S-curve would not closely fit the process. Also absent from these instances of abandonment of innovations is the phenomenon previously called "technological imperative," the strong desire or need on the part of physicians to be among the first to offer the newest brightest, and most sophisticated technologies in their practices. We saw no evidence of any "imperative" to be among the first to abandon a technology that

had been the object of unfavorable reports. It is tempting to argue that we should have expected to find the empirical picture of abandonment of these innovations to be different from the traditional model of innovation-adoption, because the processes are different. But, as yet, we have insufficient justification to expect that our findings are applicable to abandonment of technological innovation in general.

Lack of support for an S-shaped model to explain the abandonment of the drugs we studied, in turn casts doubt on the applicability, under those circumstances, of the two-step process of opinion leadership and chain reaction postulated in traditional innovation-adoption theory. Some support is offered by the results of our study for the possibility that physicians are sometimes affected directly by external information stimuli without the need for processesing by an intermediary opinion leader.[24]

The preliminary findings reported in this paper suggest the need for a systematic characterization of alternative explanatory models for the abandonment and adoption of medical technology, and the circumstances when they might apply. Alternative models could be proposed in the context of expected influences on the behavior of physicians in accepting or rejecting medical practices. The behavioral assumptions would need to be translated into a mathematical form that the behavior suggests. Testing of the model to include data access and analysis could then proceed in a manner that builds upon the approach employed here for the examination of the abandonment process of our particular sample of drugs.

REFERENCES

1. Mansfield, E. "Technical change and the rate of imitation." Econometrica, 29, 1961, 741-766.

2. Griliches, Z. "Hybird corn: An exploration in the economics of technological change." Econometrica, 25, 1957, 501-522.

3. Rogers, E.M. Diffusion of Innovations. New York: The Free Press, 1962.

4. Rogers, E.M., and Shoemaker, F.F. Communication of Innovations: A Cross-Cultural Approach. New York: The Free Press, 1971.

5. Zaltman, G. and Stiff, R. "Theories of Diffusion," in Theoretical Perspectives in Consumer Behavior, ed., S. Ward, T. Robertson. New Jersey: Prentice-Hall, 1972.

6. Fineberg, H.V. "Gastric freezing: A study of diffusion of a medical innovation," in Medical Technology and the Health Care System, National Academy of Sciences, Washington, DC: Government Printing Office, 1979.

7. Fineberg, H.V., Pearlman, L.A., and Gabel, R.A. "The case for abandonment of explosive anesthetic agents." New England Journal of Medicine, 303, 1980, 613-617.

8. Homer, J.B. "A dynamic model for analyzing the emergence of new medical technologies." Doctoral dissertation, MIT Sloan School of Management, June 1983.

9. Fourt, L.A. and Woodlock, J.W. "Early prediction of market success for new grocery products. Journal of Marketing, 26, 1960.

10. Bass, E.M. "A new product growth model for consumer durables." Management Science, 15, 1969, 215-227.

11. Kalish, S. "Control variables in models of innovation diffusion." Doctoral dissertation, MIT Sloan School of Management, 1982.

12. Nevers, J.V. Extensions of a new product growth model. Sloan Management Review, 13, 1972, 78-79.

13. Coleman, J., Katz, E. and Menzel, H. Medical Innovation: A Diffusion Study. Indianapolis: Bobbs-Merrill, 1966.

14. Russell, L.B. "The diffusion of hospital technologies: Some econometric evidence." Journal of Human Resources, 12, 1977, 482-501.

15. Manning, P.R., Denson, T.A. "How internists learned about cimetidine." Annals of Internal Medicine, 92, 1980, 690-692.

16. Warner, K. "A 'desperation-reaction' model of medical diffusion." Health Services Research, 10, 1975, 369.

17. Temin, P. Taking your Medicine: Drug Regulation in the United States. Cambridge: Harvard University Press, 1980.

18. Finkelstein, S.N., Schectman, S.B., et al. "Clinical trials and established medical practice: Two examples." In Biomedical Innovation, ed., E.B. Roberts, et al., Cambridge: MIT Press, 1981.

19. Narin, F., Pinski, G., Gee, H.H. "Structure of the biomedical literature." Journal of the American Society for Information Science, January-February, 1976, 25-45.

20. National Mail Audit, National Detailing Audit, National Journal Audit of IMS America, Ltd., various years 1966-82.

21. Fuchs, V.R. "The growing demand for medical care." New England Journal of Medicine, 279, 1968, 190-195.

22. Banta, H.D., Behney, C.J., Willems, J.S. Toward Rational Technology in Medicine. New York: Springer Publishing Company, 1981.

23. Blume, S. "Aspects of the dynamics of medical technologies." In Research on Research: Proceedings of the European Symposium, ed. E. Heinekken, et al., Helsinki: Academy of Finland, 1980.

24. Cavalli-Sforza, L.L., and Feldman, M.W., et al., "Theory and observation in cultural transmission." Science, 218, 1982, 19-27.

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